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On Some Weather Forecasting Models in Georgia

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ABSTRACT

Weather regional forecasting is the hard mathematical task especially for Georgian complex relief. Models of different complexity have been created and used to solve this problem. The results obtained from WRF and atmospheric non-stationary mesoscale models for complex orography of Georgia are presented in paper. Also existed and new approaches developed for better understanding meteorological events are discussed in conclusion.

Key words: *Numerical weather forecasting, hydrothermodynamical equations, complex orography regional forecasting systems, nonstationary mesoscale model*

1. Introduction

The relief of Georgia may be characterized by three sharply expressed orographic elements: in north Caucasus, in south – Georgian south uplands and lowland or intermountain depression located between those two risings. This one begins from The Black Sea shore by triangular Colchis Lowland and spreads up to eastern Georgia like the narrow strip. Between those two uplands small scaled orographic elements are allocated. Such complicated relief has its definite influence on air masses motion in atmosphere lower layers. Mainly western and eastern atmospheric processes prevailed over Georgian territory.

Due to complex orographic conditions and influence of the black Sea in Georgia exist most of Earths climatic types, from marine wet subtropical climate in west Georgia and steppe continental climate in east Georgia up to eternal snow and glaciers in high mountain zone of Great Caucasus, and also approximately 40% of observed landscapes. Current geodynamics and orographic properties of Georgia play an important role in formation of weather various patterns. Such complex relief conditions the formation and evolution of various scaled circulation systems and heterogeneous spatial distribution of meteorological elements. This is verified by the fact, that precipitation annual distribution has diverse type, with sharply expressed spatial inhomogeneities.

Fig.1. Climatic zoning of Caucasus region

The local circulation systems developed on the background of synoptical processes play significant role in the spatial-temporal distribution of weather determining parameters. The development of computing technique and modern sufficient methods to solve hydrodynamical differential equations leaded the creation of weather forecasting systems and gave possibility to simulate various scaled atmospheric processes. Among them mesoscale processes simulation system has been greatly developed. For present leading weather research centers develop and run real time global and regional forecasting systems. Based on mentioned modeling system Georgian weather forecasting service calculates main meteorological parameters on high resolution grid. Instead of above said operational service still needs creation of such methods that will be able to describe with high spatial-temporal decision and high quality of adequacy. This is conditioned by the fact that Georgia is mountainous country and consideration of relief in weather forecasting and modeling issues for Caucasus region is very urgent problem.

In Georgia there exist definite scientific experience in weather numerical forecasting methods, as well technological basis for use of modern models for their operational forecasting, but on preparation of short and medium-term forecasts, mainly is used various Prepayment background (mainly seven-day) forecasts issued by world's leading forecast centers obtained from special telecommunication systems and programs. Further, this information is synoptically treated for forecast region and nearby areas – considering local physical-geographical conditions. Therefore, it is natural that there is quite a severe problem in raising the issue of the reliability of the forecasts.

The computing optimal technology in numerical weather prediction methods is preferable to rely on the optimal parallelism of computing systems. In leading countries, weather forecasting massive parallelism is used in computer systems (such as supercomputers CRAY) – with large (millions or billions) working parallel processor. In this regard, the problem of weather forecasting module can be considered as the most advanced data-parallel processing technologies. In the 90s, the development of computational techniques has contributed to the explosive data parallel processing technology development, created new trends, making use of modern microprocessor technology achievements. Unfortunately, this period coincided in Georgia technical degradation, which led that the newly created lines were completely ignored (at present, there is almost no parallel programming experience in Georgia, as well as research in the commercial sector).

2. Methods

Weather numerical forecasting for whole Earth using atmosphere mathematical modeling requires huge data array transformation and complex calculations that, can't be realized without a powerful computer technology. The application of such an abundance of information in atmospheric processes study leads to the management of acceptable outputs obtained based on the ability of, complex models. The specifics of the weather forecasting assignment requires expensive (a few million or more) high-tech support, which for today is possible only for developed countries. Global weather models, with large-scale (1000 km or more) description of the process give forecasts a week ahead of schedule. In other words, issue information about the weather baseline, but can't catch relatively small-scale processes, especially when the local weather is formed by processes such as convection. Such processes can't be described in terms of global atmospheric models, which counting grid size is quite large, and therefore, the term of local weather patterns discernment is low. Despite the possibility that powerful computer systems are currently available, the local weather detection of acceptable accuracy to parse Earth using only global model is practically impossible. Thus, for local real weather prediction needs the development of regional (bounded area) models.

For short-term operational forecasting the use of confined area models became available in several national meteorological services. The range of those models is quite diverse from which special attention deserve regional mesoscale models also atmosphere dynamical models with artificial boundaries where model variables are defined from coarse value grid from global model outputs. Such models can describe real weather conditions invisible for global models that form in atmosphere small-scale processes.

Weather research and forecasting model (WRF) is weather numerical forecasting and atmosphere simulation system created as for research as operational application. The model is elaborated USA National Center for Atmosphere Research (NCAR), Mesoscale and Microscale Meteorological Division (MMM), NOAA, NCEP, ESRL, AFWA, Naval Research Laboratory, CAPS, and etc. It is used in following fields: real-time numerical forecasting, data assimilation, physical parameterization research, regional climatic simulations and etc [1].

Local area (space) model structure may be divided in dynamical and physical package. Its configuration for Caucasus region considers relevant adjustment of physical package such as local landscape-geographical properties (including: relief parameters, landuse and soil types, soil temperature, plant seasonal distribution and etc.). Dynamical core provides general circulation processes transformation influenced by Caucasus relief and proximity of The Black and Caspian Seas resulting in local established weather. The specification of those processes is possible by optimal configuration selection of schemes describing physical processes. Besides ARW provides introduction of higher spatial-temporal resolution horizontal grid that focuses on target sub-region and significantly increases model resolution (from 15km to 5 km.) [2].

Complex relief of Caucasus significantly influences on weather formation thus relief consideration in model is one of most important assignment. It may be realized by relief parameterization or statistical type or by using both of them. As calculations show Caucasus orographic is considered at high level in regional model that is proved by atmosphere boundary level pressure forecasting.

- Clearly fixed local circulation formation in west Georgia during western circulation processes;
- Also well fixed high pressure area formation in River Mtkvari valley during eastern processes and on the contrary – low pressure area in Rioni River gorge (Colchis lowland)

Mentioned facts give possibility to predict with high accuracy the beginning and end of western and eastern incursions on Georgian territory also their intensity, specifically western and eastern wind power in Mtkvari and Rioni rivers.

Model simulation outputs and analysis are given below.

The main synoptical processes and related weather patterns are: western, eastern, anticyclone state established by air masses bilateral invasion and wave perturbations in southern frontal zone. Kain-Fritsch convective cloud parameterization scheme was used (deep and non-deep convection intercellar scaled scheme) and WSM3 microphysical scheme, also YSU (Yonsei University) planetary layer scheme. The subgrid has been embedded in research model WRF ARW. Main area covered whole Caucasus region and subarea was fixed over Georgian territory with 5km resolution and 145X115 knots.

The circulation process evolution has been discussed that occurred on November 4, 2009, when air masses have been invaded from the Black Seaside resulting in snowstorm in Tbilisi. According weather observation data wind maximal velocity was more than 30m/sec resulting in temperature decreasing and precipitation in Georgia. As the front moved eastward very quickly above mentioned weather extreme conditions lasted only for several minutes. Subsequently in eastern Georgia was established anticyclone parietal impact long period with weak winds and rain as well as frog.

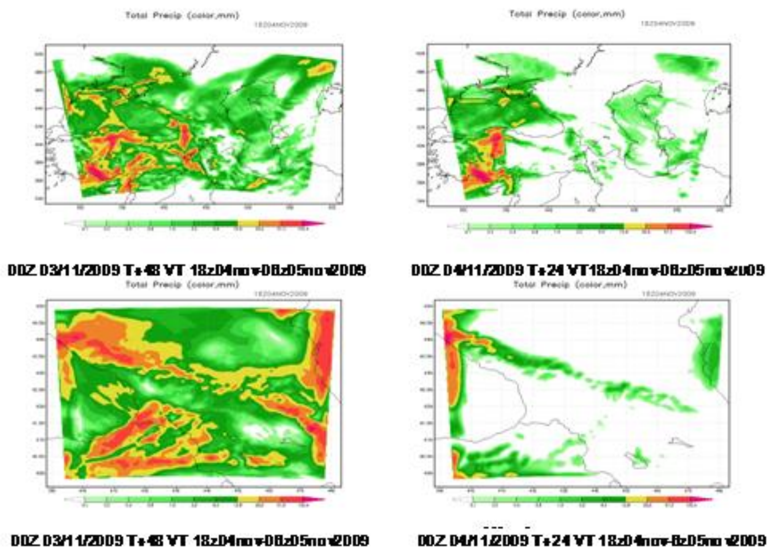


Fig.2. Precipitation distribution from WRF model for different moments

Despite above discussed method that undoubtedly is step forward national weather service still requires development of forecasting methods. Numerical forecasting models based on complete hydrothermodynamical equations give possibility detail involve physical factors describing atmospheric phenomena that greatly influenced or sometimes define atmospheric circulation processes. The consideration of those factors in numerical models provides improvement forecasting quality. Realization of weather forecasting issue on confined area is characterized by definite difficulties. Such is the formulation of boundary conditions on the borders of forecasting area. The lack of meteorological data on region borders influenced researches to seek problem solution different ways. By using telescopization or embedded grid method became one of the most effective mean for this. Except boundary conditions telescopization method gives possibility to solve those main issues that are essential for weather forecasting on confined area. Specifically reducing spatial grid step on target area in such way that didn't increase model realization time, also detail describe region orographic features, realize interconnection between largescale, regional and mesoscale meteorological processes using bilateral and unilateral interaction of solutions from different grids.

Based on atmospheric processes nonstationary mesoscale model [3] for Georgian territory the peculiarities of mesoscale flows in troposphere under conditions when undisturbed background flow undergo significant transformations and atmospheric circulation regime has been changed by another one.

Model equation solving area which's sizes among X and Y axis compose 830km and 690km is shown of fig.3. On same figure is given relief elevation revealing that integral area is characterized by sharply expressed orographic elements. Those are: Caucasus in north, Georgian southern uplands on south and placed between those two risings lowland or intermountain depression, which begins from the Black Sea coast – triangle shaped Kolkheti Lowland and extends to east Georgia in the form of narrow line. Among those two uplands a number of small scaled elements have been placed. Such relief type has definite influence on air masses motion in atmosphere lower layers over Georgian territory. 30 computing level was on vertical and on each level grid knot amount among X and Y axis compose 84 and 70 with 10km horizontal step.

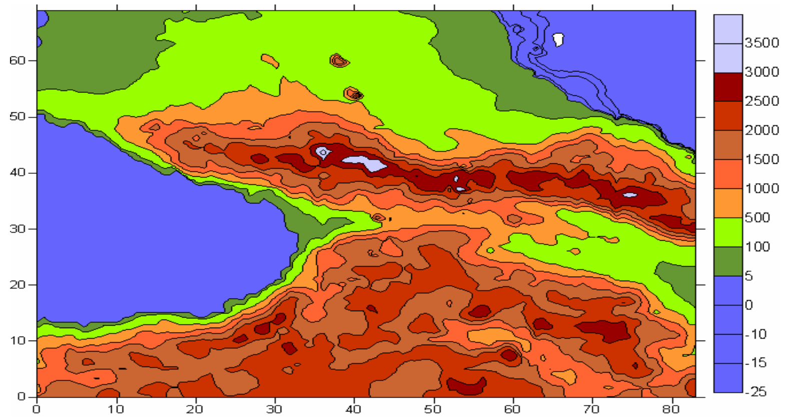
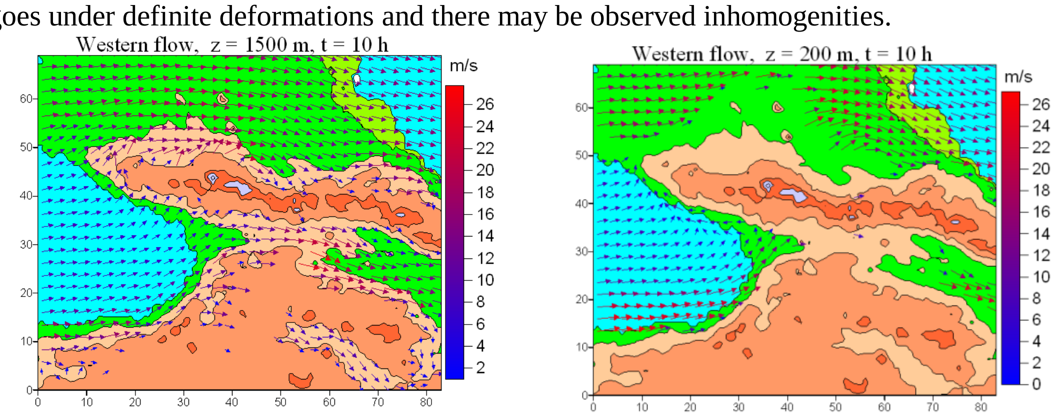


Fig.3. Georgian relief used in nonstationary mesoscale model and equation solution area.

The disturbed flow field on 200, 1500, 3000 and 5000m elevation for t=10h or before nonstationary transformation of background flow is presented on fig.4. The picture reveals that western background flow undergoes under definite deformations and there may be observed inhomogenities.



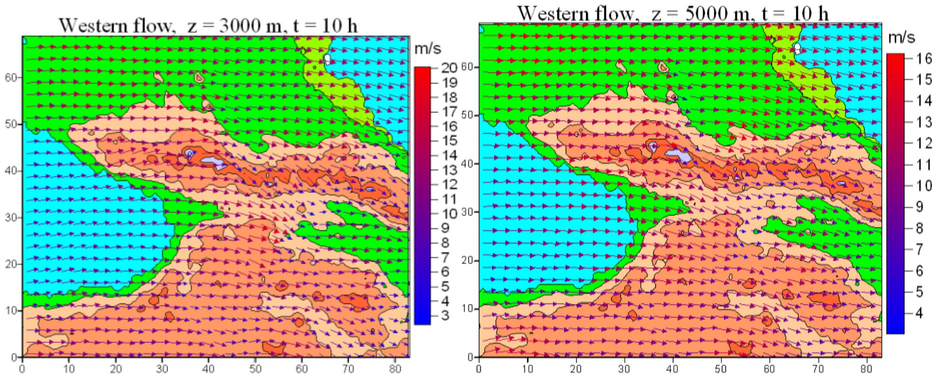


Fig 4. Simulated flow field for 10h. at different elevations.

On Fig. 5and 6 are presented simulated western flow at 200 m and 1500 m for different time moments. From those figures it is evident how relief influenced flow field.

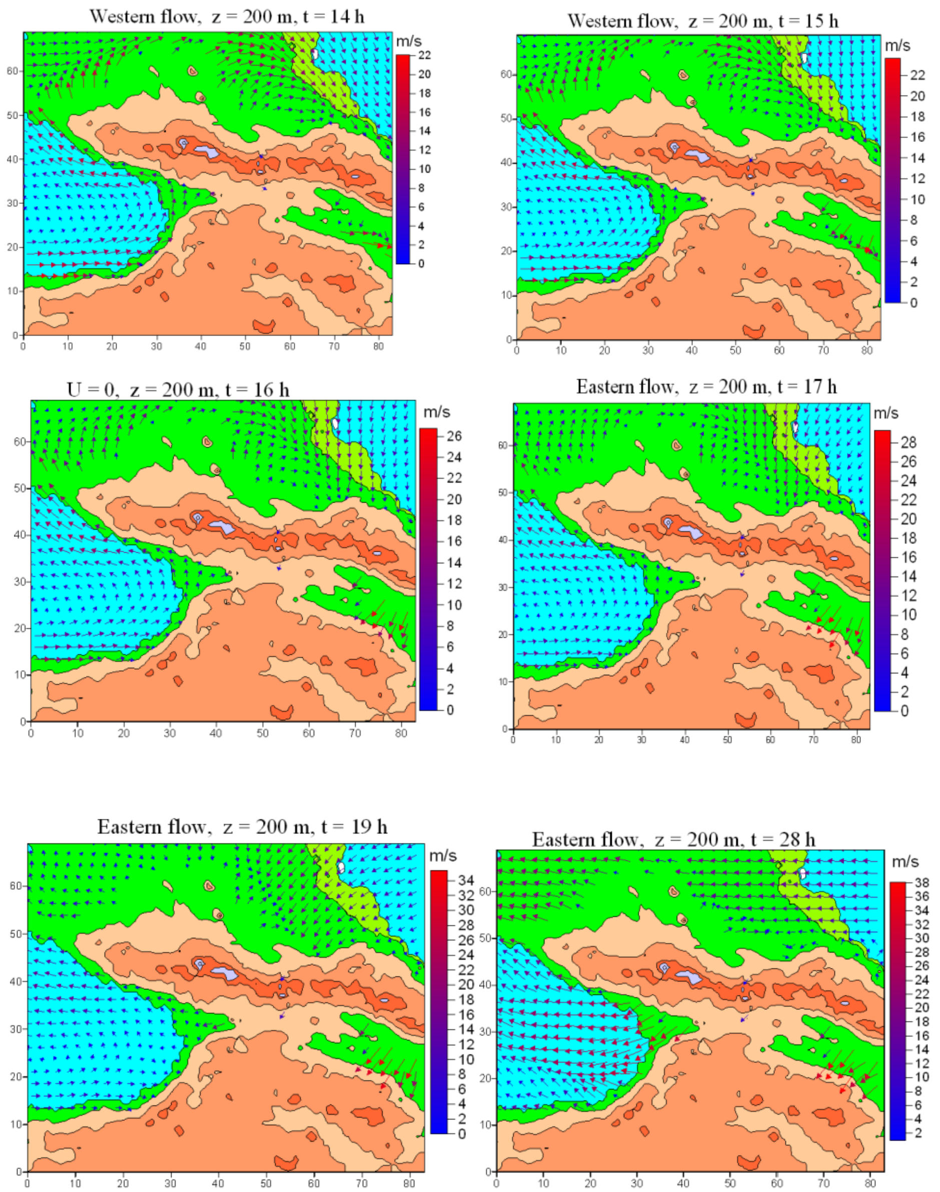


Fig 5. Simulated flow field at 200 m for different time moments.

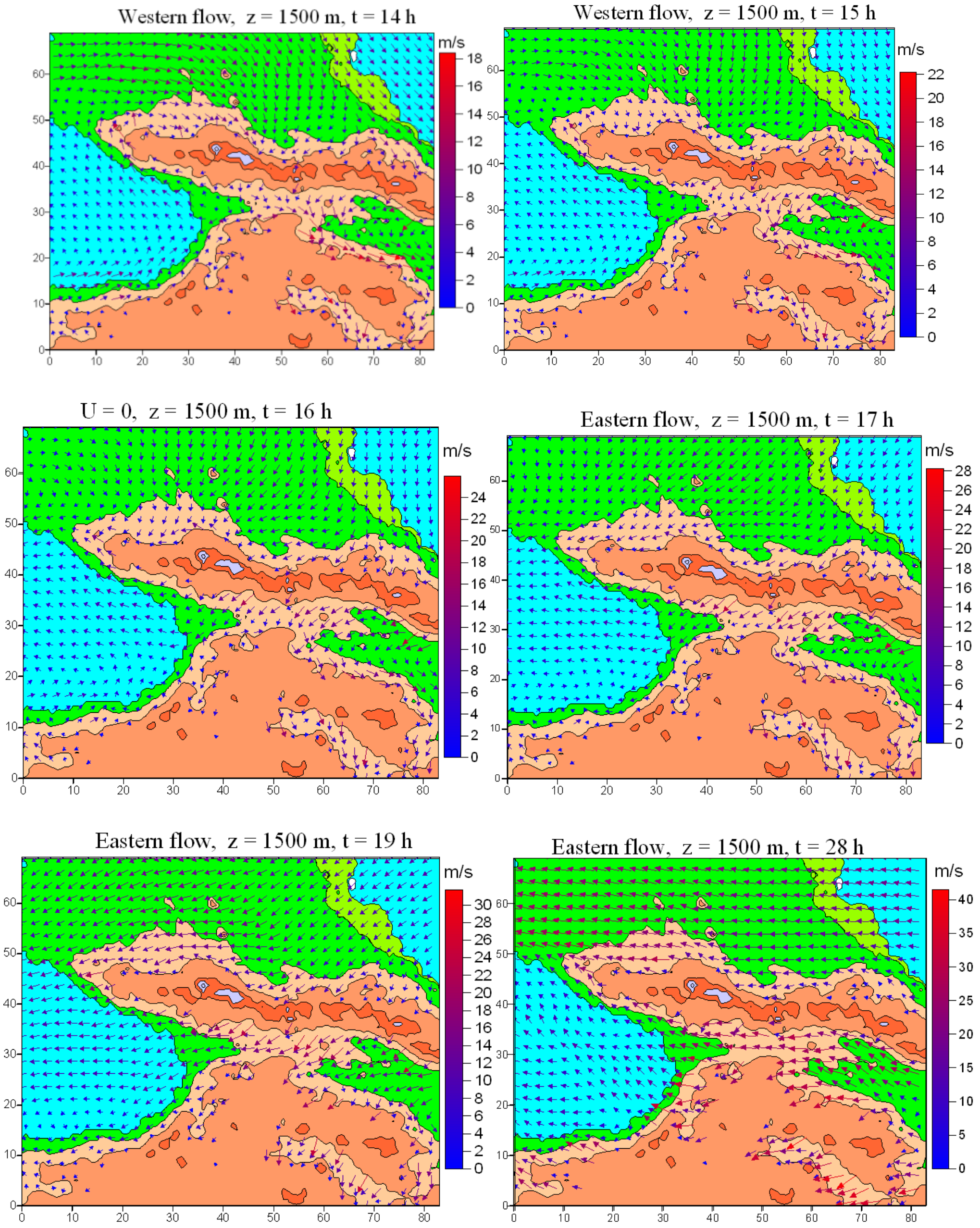


Fig 6. Simulated flow field at 1500m for different time moments

3. Conclusion.

The impact of the complex terrain is the decisive factor on local circulation processes and its detail consideration in weather forecasting models should be required. The presented two different models WRF and atmospheric nonstationary mesoscale model outputs show how it influences on precipitation and temperature fields formation. It is preferably to use other existing software packages and methods to ensure model justification and carry out adjusting –calibration towards real observations.

Except above presented models many efforts and methods have been dedicated to the problem of precipitation formation and convective cloud evolution processes for Georgian conditions. Among others it is remarkable to mention operational thermohydrodynamical convective cloud model created for research of natural and artificial precipitation formation and can be used in weather modification [4,6]. In model for crystallization and melting processes have been introduced new parameterization schemes. One of most important precipitation formation microphysical process – coagulation describing integral-differential equations have been analytically solved considering income of cloud particles. The results evidently showed redistribution of ice crystals and rain drops in cloud dispersive medium.

Many researchers and scientists remark that in weather forecasting models detail considering of cloud microphysics would be preferable but as they are microscale processes usually parameterization schemes are used. The some peculiarities of microstructure of cloud formations have been discussed using quantum disperse forces or Van-Der-Vaal's forces that are typical for water particles. To obtain the expression for interaction potential the wave functions of basic and exited states of clusters and dispersion matrix have been introduced describing by virtual photon. It has been turned out that virtual photon interaction causes potential holes and barriers that are decreased by height and width. The isolated long wave quants may be the radiation that is generated throughout observed microphysical processes. The cluster may be presented as multipole system. The multipole is the system composed by couple opposite charges that have definite symmetry type. The simplest is the dipole. If the transition is forbidden in dipole approach it may happen in higher approaches – quadruple (electric) or magnetic dipole. Their probability is approximately 10^6 times less than dipole. To search out transition probability of cluster from basic state into exciting or virtual one interacting with electromagnetic field the identification of Einstein factors have to be needed.

This new approach can lead research series in different microphysical processes such as phase transitions, electric processes and etc.

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საქართველოში ამინდის პროგნოზის ზოგიერთ მოდელების შესახებ

მ. ტატიშვილი, ზ. ხვედელიძე, დ. დემეტრაშვილი

რეზიუმე

ამინდის რეგიონალური პროგნოზი რთული მათემატიკური ამოცანაა, განსაკუთრებით საქართველოს კომპლექსური რელიეფისთვის. ამ პრობლემის გადასაჭრელად შეიქმნა და გამოყენებულია სხვადასხვა სირთულის მოდელები. წინამდებარე სტატიაში მოყვანილია WRF–ისა და ატმოსფერული არასტაციონარული მეზოსკალის მოდელებისგან მიღებული შედეგები საქართველოს რთული ოროგრაფიისთვის. დასკვნაში ასევე განხილულია შექმნილი და ახალი მიდგომები მეტეოროლოგიური მოვლენების უკეთ შესასწავლად.

О некоторых моделях прогноза погоды в Грузии

М.Р. Татишвили, З. В. Хведелидзе, Д.И. Деметрашвили

Резюме

Региональное прогнозирование погоды - сложная математическая задача, особенно для сложного рельефа Грузии. Для решения этой задачи созданы и используются модели разной сложности. В статье представлены результаты, полученные с помощью WRF и атмосферных нестационарных мезомасштабных моделей для рельефа Грузии. В заключении обсуждаются также существующие и новые подходы, разработанные для лучшего понимания метеорологических явлений.